ERIC L. SONNENTHAL, Ph.D. – Curriculum Vitae

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RESEARCH INTERESTS AND ACTIVITIES

Investigation of geochemical and isotopic processes coupled to thermal, hydrological, and mechanical effects in geological and engineered systems. Development of reaction transport models for water-gas-rock interaction applied to geological emplacement of nuclear waste, environmental remediation, enhanced geothermal systems, vadose zone transport, and CO_2 sequestration. Co-developer of the widely used multiphase reaction-transport code TOUGHREACT. Author of reaction-transport-mechanical codes for sedimentary basin compaction and multicomponent magma crystallization.

Professional Preparation

Pennsylvania State University	B.S. Geosciences, Geochemistry option, 1982
University of Oregon	Ph.D. Geological Sciences, 1990
Indiana University	Postdoctoral Fellow, Geochemistry, 1990-1993
French Institute of Petroleum	Postdoctoral Scientist, Geochemistry, 1993-1994

Appointments

Staff Geological Scientist**,** Lawrence Berkeley National Laboratory, Earth Sciences Division, 2004–.
Associate Researcher, University of California, Berkeley, Earth and Planetary Science, 2009–.
Geological Scientist**,** Lawrence Berkeley National Laboratory, Earth Sciences Division, 1996-2004.
Visiting Instructor, Department of Geological Sciences, University of Oregon, 1995.

Recently Funded Projects

Sonnenthal E. (PI). J. Rutqvist, and S. Nakagawa. DOE EGS Proposal: "Coupled Thermal-Hydrological-Mechanical-Chemical Model And Experiments For Optimization Of Enhanced Geothermal System Development And Production".

Sonnenthal E. (PI). D. Elsworth, R. Lowell, K. Maher, B. Mailloux, and N. Uzunlar. NSF Proposal: "Collaborative Research: Coupled Thermal-Hydrological-Mechanical-Chemical-Biological Experimental Facility at DUSEL Homestake".

Publications

Mukhopadhyay, S., E.L. Sonnenthal, and N. Spycher, 2009. Modeling of coupled heat transfer and reactive transport processes in porous media: Application to seepage studies at Yucca Mountain, Nevada. Journal of Porous Media, 12:725-748.

Zhang, G., N. Spycher, E. Sonnenthal, C. Steefel, and T. Xu, 2008. *Modeling reactive multiphase flow and transport of concentrated solutions,* 2008. Nuclear Technology, 164:180-195.

Lu, G., E.L. Sonnenthal, and G.S. Bodvarsson, 2008. *Multiple component end-member mixing model of dilution: hydrochemical effects of construction water at Yucca Mountain, Nevada, USA*. Hydrogeology Journal, 16:1517-1526.

Mukhopadhyay S., E.L. Sonnenthal, and N. Spycher, 2006. *Modeling coupled thermal-hydrological-chemical processes in the unsaturated fractured rock of Yucca Mountain, Nevada: heterogeneity and seepage.* Physics and Chemistry of the Earth, 31:626-633.

Xu, T., E. Sonnenthal, N. Spycher, and K. Pruess, 2006. *TOUGHREACT: A simulation program for non-isothermal multiphase reactive geochemical transport in variably saturated geologic media: Applications to geothermal injectivity and CO_2 geological sequestration.* Computers & Geosciences. 32:145-156.

Sonnenthal, E., A. Ito, N. Spycher, M. Yui, J. Apps, Y. Sugita, M. Conrad, and S. Kawakami, 2005. *Approaches to modeling coupled thermal, hydrological, and chemical processes in the Drift Scale Heater Test at Yucca Mountain*. International Journal of Rock Mechanics and Mining Sciences, 42:698-719.

Sonnenthal, E., T. Xu, and G. Bodvarsson, 2005. *Reply to "Commentary: Assessment of past infiltration fluxes through Yucca Mountain on the basis of the secondary mineral record – is it a viable methodology?"*, by Y.V. Dublyansky and S.Z. Smirnov. Journal of Contaminant Hydrology. 77: 225-231.

Sonnenthal, E.L., N.F. Spycher, M. Conrad, and J. Apps, 2004. *A conceptual and numerical model for thermal-hydrological –chemical processes in the Yucca Mountain Drift Scale Test*. In: Stephansson, O., J.A. Hudson, and L. Jing, ed., Coupled Thermo-Hydro-Mechanical-Chemical Processes in Geo-Systems, Fundamentals, Modelling, Experiments and Applications. Elsevier Geo-Engineering Book Series, volume 2, p. 347-352.

Singleton, M.J., E.L. Sonnenthal, M.E. Conrad, D.J, DePaolo, and G.W. Gee, 2004. *Multiphase reactive transport modeling of stable isotope fractionation in unsaturated zone pore water and vapor: Application to seasonal infiltration events at the Hanford Site, WA.* Vadose Zone Journal, 3: 775-785.

Dobson, P.F., S. Salah, N. Spycher, and E.L. Sonnenthal, 2004. *Simulation of water-rock interaction in the Yellowstone geothermal system using TOUGHREACT*. Geothermics 33: 493-502.

Lu, G., E.L. Sonnenthal, and G.S. Bodvarsson, 2003. *Implications of halide leaching on chlorine-36 studies at Yucca Mountain, Nevada*. Water Resources Research, 39(12): 1361, 3-1-15.

Xu, T., E. Sonnenthal, and G.S. Bodvarsson, 2003. *A reaction-transport model for calcite precipitation and evaluation of infiltration fluxes in unsaturated fractured rock*. Journal of Contaminant Hydrology, 64:113-127.

Dobson, P.F., T.J. Kneafsey, E.L. Sonnenthal, N.F. Spycher, and J.A. Apps, 2003. *Experimental and numerical simulation of dissolution and precipitation: Implications for fracture sealing at Yucca Mountain, Nevada*. Journal of Contaminant Hydrology. 62-63: 459-476.

Liu, J., E. Sonnenthal, and G.S. Bodvarsson, 2003. *Modeling of porewater chloride data to calibrate flow and transport processes in the unsaturated Zone at Yucca Mountain, Nevada*. Journal of Contaminant Hydrology. 62-63: 213-235.

Spycher, N., E. Sonnenthal, and J. Apps, 2003. *Prediction of fluid flow and reactive transport around potential nuclear waste emplacement tunnels at Yucca Mountain, Nevada*. Journal of Contaminant Hydrology, 62-63: 653-673.

Bodvarsson, G.S., H.H. Liu, C.F. Ahlers, Y.S. Wu, and E.L. Sonnenthal, 2001. *Parameterization and upscaling in modeling flow and transport at Yucca Mountain*. In: Conceptual Models of Flow and Transport in the Fractured Vadose Zone, Chapter 11. National Academy of Sciences, National Academy Press, Wash. D.C., 335-365.

Xu, T., E. Sonnenthal, N. Spycher, K. Pruess, G. Brimhall, and J.A. Apps, 2001. *Modeling multiphase fluid flow and reactive geochemical transport in variably saturated fractured rocks: 2. Applications to supergene copper enrichment and hydrothermal flows*. American Journal of Science, 301: 34-59.

Bodvarsson, G.S., S. Finsterle, H.H. Liu, C.M. Oldenburg, K. Pruess, E. Sonnenthal, and Y-S. Wu, 2000. *Flow and Transport Modeling of Subsurface Systems*. In: Vadose Zone Science and Technology Solutions, Chapter 5. B.B. Loomy and F.W. Falta, eds. Battelle Press: Columbus, Ohio, 2: 591-784.

Sonnenthal, E.L. and G.S. Bodvarsson, 1999. *Constraints on the hydrology of the unsaturated zone and infiltration at Yucca Mountain, Nevada from three-dimensional models of chloride and strontium geochemistry*, Journal of Contaminant Hydrology, 38: 107-156.

Sonnenthal, E.L. and A.R. McBirney, 1998. *The Skaergaard Layered Series. Part IV. Reaction-transport simulations of foundered blocks*. Journal of Petrology, 39(4): 633-661.

Sonnenthal, E.L. and P.J. Ortoleva, 1994. *Numerical simulation of overpressured compartments in sedimentary basins*. In: Basin Compartments and Seals, American Association of Petroleum Geologists Memoir 61, 403-416.

Sonnenthal, E.L., 1992. *Geochemistry of dendritic anorthosites and associated pegmatites in the Skaergaard Intrusion, East Greenland: Evidence for metasomatism by a chlorine-rich fluid*. Journal of Volcanology and Geothermal Research, 52: 209-230.

McBirney, A.R. and E.L. Sonnenthal, 1990. *Metasomatic processes in the Skaergaard Intrusion: preliminary observations*. Chemical Geology, 88: 245-260.

Roy, D.M., E. Sonnenthal and R. Prave, 1985. *Hydrotalcite observed in mortars exposed to sulfate solutions.* Cement and Concrete Research, 15: 912-916.

Proceedings Papers (since 2006)

Aradottir, E.S.P., E. Sonnenthal, G. Bjornsson, E. Gunnlaugsson, and H. Jonsson, 2009. *Development of a coupled reactive fluid flow model for mineral CO_2 capture in Hellisheidi, Iceland*. TOUGH Symposium 2009.

Druhan, J., E. Sonnenthal, and D. DePaolo, 2009. *Investigation of strontium isotopic exchange in single and dual continua using TOUGHREACT.* TOUGH Symposium 2009.

Gupta, I., G. Jones, and E. Sonnenthal, 2009. *Reaction transport models of structurally controlled hydrothermal dolomite in carbonate reservoirs*. TOUGH Symposium 2009.

Pau, G.S.H., A.S. Almgren, J.B. Bell, M.J. Lijewski, E. Sonnenthal, N. Spycher, T. Xu, and G. Zhang, 2009. *A parallel second-order adaptive mesh algorithm for reactive flow in geochemical systems.* TOUGH Symposium 2009.

Xu, T., E. Sonnenthal, N. Spycher, G. Zhang, L. Zheng, and K. Pruess, 2009. *TOUGHREACT Version 2.0*. TOUGH Symposium 2009.

Birkholzer, J.T., D. Barr, J. Rutqvist, E. Sonnenthal, 2006. *Motivation, description, and summary status of geomechanical and geochemical modeling studies in Task D of the international DECOVALEX-THMC project.* In: Advances on Coupled Thermo-Hydro-Mechanical-Chemical Processes in Geosystems and Engineering, Proceedings of the GEOPROC2006 International Symposium, Nanjing, China. 91-96.

Dobson, P., Sonnenthal, E., Kennedy, M., Van Soest, T., and Lewicki, J., 2006. *Temporal changes in noble gas compositions within the Aidlin sector of The Geysers geothermal system.* Transactions, Geothermal Resources Council, 2006 Annual Meeting.

Dobson, P., Sonnenthal, E., Lewicki, J., and Kennedy, M., 2006. *Evaluation of C-14 as a natural tracer for injected fluids at the Aidlin sector of The Geysers geothermal system through modeling of mineral-water-gas reactions*. Proceedings, TOUGH Symposium 2006, LBNL, Berkeley, CA, May 15-17, 2006.

Hubbard, S., J. Chen, Y. Fang, K. Williams, S. Mukhopadhyay, E. Sonnenthal, K. McFarlane, N. Linde and T. Scheibe, 2006. *Improved parameterization of hydrological models and reduction of geophysical monitoring data ambiguity through joint use of geophysical and numerical modeling methods*. Invited Keynote Speaker, CWMR, Copenhagen, June 19-23, 2006.

Rutqvist, J., X-T Feng, J. Hudson, L. Jing, A. Kobayashi, T. Koyama, P-Z Pan, H-S Lee, M. Rinne, E. Sonnenthal, and Y. Yamamoto, 2006. *Multiple-code benchmark simulation of coupled THMC processes in the excavation disturbed zone associated with geological nuclear waste repositories.* In: Advances on Coupled Thermo-Hydro-Mechanical-Chemical Processes in Geosystems and Engineering, Proceedings of the GEOPROC2006 International Symposium, Nanjing, China. 397-402.

Xie, M., E. Sonnenthal, W. Wang, O. Kolditz, J.T. Birkholzer, J. Rutqvist, Y. Oda, and M. Chijimatsu, 2006. *Geochemical predictions for a hypothetical repository located in crystalline rock – comparative evaluation of different research teams.* In: Advances on Coupled Thermo-Hydro-Mechanical-Chemical Processes in Geosystems and Engineering, Proceedings of the GEOPROC2006 International Symposium, Nanjing, China. 403-410.

Zhang, G., N. Spycher, Sonnenthal, E., and C. Steefel, 2006. *Implementation of a Pitzer Activity Model into TOUGHREACT for Modeling Concentrated Solutions.* Proceedings, TOUGH Symposium 2006, LBNL, Berkeley, CA, May 15-17, 2006.

Recent Abstracts (since 2006)

Sonnenthal, E., 2008. *Multi-continuum reaction transport modeling of low-temperature alteration and mechano-chemical processes in fractured rock*. AGU Chapman Conference on Shallow Mantle Composition and Dynamics Fifth International Orogenic Lherzolite Conference. Mount Shasta, CA, p. 69.

Rutqvist, J., A. Bäckstrom, M. Chijimatsu, X-T Feng, P-Z Pan, J. Hudson, L. Jing, A. Kobayashi, T. Koyama, H-S Lee, X-H Huang, M. Rinne, B. Shen, and E. Sonnenthal. *Assessment of modelling approaches for analysis of coupled THMC processes in the EDZ of geological nuclear waste repositories*, GeoProc 2008, Lille, France.

Mukhopadhyay, S., E. Sonnenthal, B. Faybishenko, and S. Hubbard, 2008. *A reactive transport model for lactate stimulated hexavalent chromium reduction at Hanford 100H site*, Computational Methods in Water Resources, San Francisco, CA.

Zhang, G., N. Spycher, E. Sonnenthal, and C. Steefel, 2008. *Geochemical reactive transport modeling of boiling/evaporative dryout in porous/fractured rock*, Computational Methods in Water Resources, San Francisco, CA.

Sonnenthal, E., K. Pruess, N. Spycher, and T. Xu, 2008, *Modeling coupled thermal, hydrological, and chemical processes associated with the site analysis and emplacement of high-level nuclear waste into a geologic repository*, International Workshop on Modelling Reactive Transport in Porous Media, Strasbourg, France, Jan. 21-24, 2008. Invited.

McBirney, A. and E. Sonnenthal, 2007, *Searching for a better understanding of differentiation in the Skaergaard Intrusion*, Eos Trans. AGU, 88(52), Fall Meet. Suppl., Abstract V53D-05.

Sonnenthal, E. and A. McBirney, 2007, *Compositional convection-driven differentiation in the Skaergaard Intrusion: A Reaction-Transport Model*, Eos Trans. AGU, 88(52), Fall Meet. Suppl., Abstract V54A-05.

Zhang, G., N. Spycher, E. Sonnenthal, and C. Steefel, 2007, *Coupling seepage and radionuclide transport in and around emplacement drifts at Yucca Mountain*, Eos Trans. AGU, 88(52), Fall Meet. Suppl., Abstract H14C-05.

Birkholzer, J.T., D. Barr, J. Rutqvist, E. Sonnenthal, 2006. *Geomechanical/geochemical modeling studies conducted within the International DECOVALEX Project*. International High Level Nuclear Waste Management Conference 2006, Las Vegas, NV. LBNL-59050 Ext. Abs.

Synergistic Activities

TOUGH Symposium 2009, co-organizer

Recent Invited Presentations: UC Berkeley Earth and Planetary Science Dept. Fall Colloquim, Fall 2008; International Workshop on Modelling Reactive Transport in Porous Media, Strasbourg, France, Jan. 21-24, 2008; Global Nuclear Energy Partnership: Waste Form S&T and Modeling & Simulation Workshop, Univ. of Michigan, Ann Arbor, MI, Jan. 29-31, 2008.

TOUGHREACT Training Course Development and Instruction **(**courses in 2007, 2008, and Sept. 2009).

TOUGHREACT Reaction-transport code co-developer (Xu, T., E. Sonnenthal, N. Spycher, and K. Pruess). Available from Dept. of Energy Software Center, and widely used internationally in universities, national laboratories, and industry.

Working Group Leader – Deep Underground Science and Science and Engineering Laboratory (DUSEL) Induced Flow, Transport, and Activity, (2004-2006, 2008)

International DECOVALEX-THMC Project: Coupled Thermal-Hydrological-Mechanical-Chemical processes, Lead for THC tasks, 2005-2007.

Collaborators & Other Affiliations

Collaborators and Co-authors: J. Birkholzer (LBNL), Z. Chengyuan (Chinese Acad. Sci.), M. Chijimatsu (JAEA, Japan), M. Conrad (LBNL), D. DePaolo (UC Berkeley/LBNL), P. Dobson (LBNL), D. Elsworth (Penn State Univ.), B. Faybishenko (LBNL), S. Finsterle (LBNL), K. Fujisaki (Quintessa, Japan), T. Fujita (JAEA, Japan), I. Gaus (NAGRA, Switzerland), E. Hardin (Sandia Nat. Lab, NM), J. Houseworth (LBNL), S. Hubbard (LBNL), G. Jones (Chevron), M. Kennedy (LBNL), O. Kolditz (Tech. Univ. Dresden), G. Lu (unaffiliated), A.R. McBirney (Univ. of Oregon), C. McDermott (Univ. Edinburgh, S. Mukhopadhyay (LBNL), Y. Oda (JAEA, Japan), Scotland), L. Quansheng (Chinese Acad. Sci.), J. Rutqvist (LBNL), H. Shao (BGR, Hannover), N. Spycher (LBNL), C. Steefel (LBNL), W. Wang (UFZ, Leipzig), M. Xie (GRS, Braunschweig), L. Xiaoyan (Chinese Acad. Sci.), T. Xu (LBNL), G. Zhang (LBNL).

Recent Student Mentoring

Jenny Druhan, 2008-present. Ph.D. student. University of California, Berkeley.

Edda Arradottir, 2007-present. Ph.D. student. University of Iceland and Reykjavik Energy.

Ipsita Gupta, 2008. University of South Carolina and intern at Chevron.